# APPENDIX C

## INNOVATIVE DOMESTIC AND COMMERCIAL WASTEWATER TREATMENT FOR RURAL KENTUCKY

* From, Water Resource Related Environmental Issues, Kentucky 5th Congressional District Congressman Rogers, Draft Report, May 28 1997.

**Innovative Domestic and Commercial**
**Wastewater Treatment for Rural Kentucky**

## A) INTRODUCTION

Many homes and commercial buildings in America have no wastewater treatment system. They discharge directly into a receiving stream causing odors, health risks, and environmental damage. They are generally illegal. The bulk of the American homes and businesses are served by either a publicly owned wastewater treatment system or a septic tank and a drain field (leach field). Holding tanks are also used occasionally In remote areas where land is at a premium. Finally, there are a few exotic systems in use in extreme conditions where more conventional systems will not work.

1) **Publicly owned wastewater treatment (POWT) systems** The most popular form of waste water treatment is a publicly owned and operated sewer system. Domestic and commercial buildings are connected to a sewer main which conveys the sewage to a treatment plant. This is, by far, the preferred process. Except for paying a connection charge and a monthly service charge, home and business owners are free from concerns about the system. Professional public or private individuals design, build, operate, and maintain the systems and are responsible to government regulators for their safe and effective operation. POWTs generally have primary treatment for solids removal and secondary or biological treatment. Some of the larger municipal systems also have tertiary treatment. Costs per residence for connecting to a POWT is generally within the $15 to $50 per month range.

The biggest disadvantages of publicly owned sewer systems are the high cost of building and operating the system, and in connecting sparsely populated and remote regions of the service area to the system. POWT system costs vary widely, depending upon energy costs, service size, population, treatment efficiency, etc. POWTs will not be discussed further in this paper.

2) **Privately owned wastewater treatment systems** The second common waste water treatment system is a privately owned septic tank followed by a drain field, or leach field. Generally, these systems are economical to build and work effectively where soils are adequate and there is sufficient room for an appropriate sized drain field system. When soils are inadequate or the drain field is too small, wastewater leaches into the ground water or puddles on the surface causing environmental and health concerns. Maintenance for most systems is relatively easy and inexpensive consisting of periodic pumping of the septic tank. There are many possible variations and improvements to these systems. They will be discussed in detail in paragraphs B and C.

3) **Holding Tanks** Holding tanks are very common in boats and recreational vehicles and are used in remote areas. They accumulate waste products until full, after which they are pumped out by a commercial wastewater hauling company. The company transports the waste to a commercial or state operated dumping site. Holding tanks will be discussed in detail in paragraph D.

4) **Exotic wastewater treatment systems** There are also several exotic systems which have been successfully used in special circumstances and several others which are still considered experimental. They include membrane technology, reverse osmosis, and desalinization. While effective in certain scenarios, they are generally expensive, involve specialized technical know how, and require considerable operation and maintenance attention. They will not be discussed further in this paper.

## B) SEPTIC SYSTEMS

1) **Septic Systems** Septic systems consist of a septic tank, a collection system and a secondary treatment facility. Traditionally, the collection system consists of a gravity fed pipe between the septic tank and a drain field.

2) **Septic Tanks** A septic tank is generally a prefabricated watertight tank made of concrete or fiberglass. It is analogous to the primary process in a POWT system because it removes solids through settling and greases through skimming. The settled materials, or septic sludge, is decomposed by anaerobic bacterial action. The effluent from the septic tank is an organic liquid containing micro-organisms and can be a major source of waterborne disease particularly where the effluent contaminates one or more drinking wells. Aerobic (Aeration) tanks can be used in lieu of septic tanks to serve a similar purpose. They operate by aerobic rather than anaerobic digestion and produce a cleaner effluent reducing the size of subsequent secondary systems. However, they cost two to five times more than a septic tank

When a septic tank is properly sized, constructed and operated, the anaerobic bacteria will keep pace with the influent waste water solids, reducing the accumulation of septic sludge to a minimum and all but eliminating the requirement for periodic pumping of the tank. When the bacteria are killed or inhibited by chemicals in the wastewater, such as chlorine, or when they become overloaded, anaerobic digestion of the solids can be suppressed or eliminated necessitating frequent pumping of the septic tank. When the bacteria are totally destroyed, they must be reintroduced into the tank through inoculation. Anaerobic bacteria do not digest non-organic solids which will accumulate in the tank and require eventual removal by pumping Consequently, successful septic tank operations require minimizing the presence of nonorganic solids in the waste water.

Although common, burial of the septic tanks is not required. Burying is required by the need to place the tank below the lowest point in the home's sewer lines to take advantage of gravity flow. Tank burial is also more aesthetically pleasing. Where buildings are being raised due to flooding or where underground construction is not possible they may be placed on the ground surface, or even elevated. Septic tanks are generally associated with individual homes, but where hydraulic conditions permit, several homes could be connected to a common septic tank. Single home septic tanks are "off the shelf' units and range from $1,000 to $1,500. A multi-home tank would be larger and could require special construction.

3) **Collection System** Septic tanks are connected to the secondary treatment system by a connection system. Most collection systems are unpressurized or gravity fed. Pressurized collection systems are more expensive and more complex but may be required in situations where the effluent is piped long distances or up hill. Two common types of pressurized systems force mains and STEP systems.

Force mains use small grinder pumps at each residence to feed sewage under pressure to collection main which may be either pressurized or gravity fed.

STEP (Septic Tank Effluent Pump) is a special types of force main. A high head pump mounted in a screened vault in the septic tank pumps liquids through a small diameter collection system to the nearest collection junction. Pressurized systems use smaller pipes and may save construction costs over a long distance. In addition, pressurized systems can change the hydraulics of some secondary systems allowing them to be smaller.

Typical collection system costs are $35-45 per linear foot of gravity main, $4-8 per linear foot of force main and $2-5 per linear foot of STEP mains. Force mains also require grinder pumps at $5,000 per home and STEP systems use pumps costing $1,500 - 3,000 per septic tank.

4) **Secondary Treatment** Secondary treatment is necessary to protect the environment and health and safety. They work by biologically breaking complex organic materials into simple, more stable and less harmful substances. The output of secondary systems consists of gasses, water and nutrients. Gasses infiltrate the soil and are released into the atmosphere. Nutrients are picked up and used for growth by the plants. Water either evaporates from the soil directly, is transpired from the plants, or is filtered through the soil to a ground water or surface water source.

a) Drain Fields(DF) Properly constructed and maintained drain fields provide a considerable amount of secondary treatment. A drain field consists of a series of perforated pipe placed in narrow, relatively shallow trenches filled with gravel. Effluent is distributed by the perforated pipe and gravel to the soil. Water, gases and nutrients are separated as the effluent filters through the soil and/or is picked up by vegetation. As long as the effluent is taken up by the plants or evaporates off the soil, and all impurities stay in the soil layers, health and safety are not a concern. Difficulties arise when the effluent ponds on top of the soil or passes directly into the ground water or tributary streams. Ponding occurs when drain fields are under sized, are placed in poorly draining soils, become clogged, or are crushed by vehicular traffic. Passing directly to the ground or surface waters is due to the use of very coarse soil allowing the waste water to infiltrate too fast, not allowing sufficient time for treatment. A drain field can be constructed for $2-5,000 per home.

b) Constructed Wetlands (CW) Constructed wetlands can be used for secondary treatment where space allows. Normally the wetland consists of two surface cells approximately one foot deep. The first cell is lined and filled with gravel. The second cell is unlined and filled with sand. Both are covered with 1-3 inches of organic material such as top soil or straw which is used to grow typical wetland plants such as water primrose, cattails or bulrushes. The plants help treat the effluent by utilizing the nutrients in growth, and reduce water volume through transpiration. Water that is not evaporated or transpired passes through the bottom of the wetlands into the soil, and eventually to a surface or ground water source. While essentially maintenance free, periodic harvesting or plant management is required and burrowing animals such as muskrats should be discouraged from destroying the liner. Wetland size and cost depend upon influent volumes. A single family home would require a wetland of approximately 450 square feet and would cost in the range of $3-5,000.

c) Intermittent Sand Filters (ISF) An ISF is a shallow sand bed, 24-30 inches deep with a surface distribution and an underdrain collection system. It is used for single family residences where soil cover is shallow, percolation rates are poor, there is a high ground water table, slopes are steep, or area is limited. The water is distributed across the filter and allowed to percolate through the bed to the collection system where it is then discharged into a drain field or disinfected and discharged into surface waters. Physical, chemical, and biological treatment processes occur in the filter as long as aerobic conditions are maintained. The filter also removes solids. The primary advantage is a reduce drain field area. An intermittent sand filter costs $5-10,000 per home.

d) Recirculating Sand Filters (RSF) A recirculating sand filter works the same as an intermittent sand filter except that the water collected in the underdrain, is pumped back into the distribution system, and passes through the sand filter many times before being discharged. Due to their costs which range from $15-30,000, they are generally limited to multiple residence systems.

e) Sand Mounds (SM) Sand mounds are similar to drain fields except that they are constructed on top of the ground surface. They are used where soil conditions are too poor to allow a traditional drain field. A network of perforated pipe in shallow gravel trenches is constructed within the mound for distributing the effluent to the sand. Grasses, or other shallow root vegetation is planted in the top soil placed on top of the mound. Physical, biological, and chemical treatment occurs in the sand mound and in the surface vegetation.

Water, which is not removed by transpiration, drains from the mound into the **ground surface** and then to surface or ground water sources. A single residence mound will cost $8-15,000.

f) Package Plants (PP) Package plants are commercially available, prefabricated treatment plants often used to treat the wastewater of small communities. Properly sized, operated and maintained, they provide satisfactory treatment of small wastewater flows. They utilize various techniques to provide several treatment processes including, screening, sedimentation, aeration and chlorination, Package Plants require less land than recirculating sand filters but cost more, require more energy and are more sophisticated to operate. Typical package plants range between $10,000 and $30,000 depending upon size and treatment process used.

## C) CLUSTER GROUPS

Often, small communities can be economically connected in a cluster. This is particularly useful when soil conditions are inappropriate or when lot sizes are insufficient for a properly constructed drain field. A "small" community can be any size and is primarily determined by topography and building proximity and is generally chosen to keep connection distances to a minimum and minimize hydraulic complexity.

Cluster groups consist of septic tank at each building, or groups of buildings connected to a community operated secondary treatment facility. Although it is possible to connect all of the buildings to a common septic tank, hydraulic flow of solids is problematic and such a system would probably have to use expensive pumps capable of pumping solids and grits as well as liquids. It might, however, make sense to connect two or three buildings in close proximity to each other to a central septic tank.

Gravity collection from the septic tanks is the most common and preferred way to convey the effluent to the group's secondary treatment facility. Where topography doesn't permit a gravity collection, a force main may be used. Use of a septic tank effluent pump (STEP) system is a special type of force main which utilizes pumps added to each septic tank to put the effluent into a small diameter pressurized collection facility. They are effective for carrying effluent long distances or uphill and where the terrain is particularly rugged.

## D) HOLDING TANKS

There are two types of holding tank systems, separate and combined. The first, separate "black water" from "gray water". Gray water is generated by washing, showering, cooking and laundering functions performed in the home. Black water is generated in the evacuation and flushing of human wastes.

Where separate systems are used, gray water is treated traditionally or released into the environment without treatment. Black water is held in tanks, often called "chemical toilets" and is pumped periodically. Chemicals are used to reduce odors and are common in small boats and recreational vehicles or in stand alone portable toilets typically seen in construction sites and remote recreational areas. If treatment of gray water can be ignored or handled easily, the use of separate systems reduce the volume of black water which must be pumped hauled and treated. Separate systems are rarely economical and It is unlikely that separate systems would be suitable or accepted in eastern Kentucky.

Combined systems hold both the gray and black water and also require periodic pumping or emptying at commercial or state operated dumping sites. They are more common in larger boats and recreational vehicles and for residences. The primary advantage is that both forms of wastewater are treated together, but the volume treated is very much larger.

Combined systems have three components as follows: a) a treatment facility, b) a hauling service, and c) a holding tank.

Wastewater haulers are subject to the same discharge requirements as other businesses and must either treat collected wastewater in their own regulated treatment facility, or dump the wastewater in a commercial or publicly owned facility. These facilities are over designed to accommodate future community growth. It is cost effective to use this excess capacity to treat wastes hauled to the site by truck from private or public waste hauling companies. As a general rule, facilities with excess capacity will accept waste from a hauler for a specific dumping fee based on the facilities need to recover costs. Dumping fees will vary widely depending upon climate, location, terrain, age of the plant and the degree of excess capacity. No dumping fees were obtained for this report. The transportation costs in the following paragraph include the dumping fees.

Hauling companies periodically pump out the holding tanks and transport the wastes to a treatment facility. The limiting factor in the design of a holding tank system is the maximum size of the tanks on the vehicles used to haul the wastes. This in turn is generally limited by the quality of the access roads during bad weather conditions. In this region, the tanks on vehicles used to pump septic tanks hold approximately 5000 gal. Kentucky's design standard for a two bedroom residence is 240 gal/day or 1680 gal/week. Consequently each truck could handle three weeks worth of waste water from a typical two bedroom residence. Assuming, one round trip per day each truck could serve about 20 homes. The costs of operating this service depends primarily upon the costs of the truck and labor but also include fuel, maintenance, insurance, licensing, profit and dumping fees. A typical price for pumping a septic tank in this region is $150 for a 1000 gallon tank or $750 for a 5000 gallon truck. Assuming a 60 percent reduction due to economies of scale, it should be possible to reduce the cost to $300 per trip, which translates into $400 per residence per month.

Holding tanks are simple but require adequate sizing, ventilation and foundation preparation. A 5000 gallon tank holding three weeks of waste water would cost $2500 to $3000. Foundation preparation, hookup, and placement costs could double that number. If three homes were located relatively close to each other, the truck described above could handle three homes, once a week as easily as one home every three weeks. This would reduce odor problems, reduce foundation preparation and require smaller holding tanks. A 1500 gal tank could be purchased and installed for about $1500 to $2500 which would handle a week of wastewater accumulation.

## E) <u>COST COMPARISON</u>

The purchase/construction price of treatment components discussed in this paper are presented in Table 1. These costs are typical costs found in the literature and do not necessarily represent the costs of similar units constructed in the Eastern Kentucky Area. Also, the fact that an item is listed does not mean it could be effectively utilized in all applications.

Figure 1 represents a typical cluster system for nine residences. It is used as an assumed community for pricing various complete cluster systems based upon the unit prices in Table 1. The cluster costs for various technologies discussed in this paper are given in Table 2. Note that these tables are not site specific and do not cover design, land, operation or administration costs. They are suitable only for making some general comparisons between the relative costs of one type of system over another.

In general the cost to treat the wastewater of nine homes will range between $50,000 and $100,000 depending upon construction limitations. For individual systems, the traditional septic tank and drain field is the cheapest, assuming sufficient room and soils to construct adequate drain fields. For cluster systems, a STEP system with wetland is the cheapest, cheaper even than the traditional individual system. Cluster systems in Table 2 using force main collection systems assume the use of a single septic tank handling all nine residences. Economies of scale in the cluster system secondary treatment were assumed to be 50% for wetlands and 25% for drain fields and sand mounds.

**Table 1 UNIT COSTS FOR SEPTIC SYSTEM COMPONENTS**

| Treatment System | Unit Costs |
|---|---|
| Primary Systems | |
| Septic tank per residence | $1000-1500 |
| Aerobic (Aeration) (per residence) | $3000-7000 |
| Collection Systems | |
| Gravity per linear foot | $35-45 |
| Force Main | |
| Grinder pump per residence | $2000-5000 |
| Main per linear foot | $4-8 |
| STEP | |
| Tank & pump per residence | $2500-5000 |
| Main per linear foot | $2-5 |
| Secondary Treatment Systems | |
| Drain field per residence | $2000-5000 |
| Mound per residence | $8000-15000 |
| Package plan per unit | $10000-30000 |
| Constructed wetlands per residence | $3000-5000 |
| Intermittent sand filters per residence | $5000-10000 |
| Recirculating sand filter per unit | $15000-30000 |

| System | Gravity Fed ($1000) | Force Main ($1000) | STEP ($1000) |
|---|---|---|---|
| **Individual Residence** | | | |
| Septic tank and drain field | 48.2 | N/A | 65.7 |
| Aerobic tank and drain field | 81.9 | N/A | 99.5 |
| Septic tank and intermittent SF | 84.2 | N/A | 101.7 |
| | | | |
| **Cluster System** | | | |
| Septic Tanks & Wetland | 74.9 | 54.8 | 43.0 |
| Septic Tanks & Drain Field | 107.5 | 87.4 | 75.6 |
| Septic Tanks & Package Plant | 76.9 | 56.8 | 45.0 |
| Septic Tank & Recirculating SF | 79.4 | 59.3 | 47.5 |
| Septic Tank & Sand Mound | 80.5 | 60.4 | 48.6 |

It is difficult to predict the cost of connecting the nine homes to a public wastewater treatment facility without knowing the cost of connecting them to the nearest sewer main and the associated POWT treatment costs. However, if the normal range of $15-$50 per month per residence were to hold, the treatment costs for the nine homes would range between $135 and $450 per month. Assuming costs of $100 per month to account for the rugged terrain in the region, the costs would be $900 per month.

If the nine home were equipped with holding tanks and serviced by a hauling company, the costs for treating the sewage would be $9,000 for the tanks and $3,600 per month for the service. This assumes the homes are connected to three tanks and pumped weekly.

## F) DESIGN AND POLICY ISSUES

The following design considerations and/or policy issues need to be addressed in the design of any small community system in either. They present opportunities to partner with state and other federal agencies to develop policies, procedures and funding sources to develop innovative wastewater treatment in the region.

1 ) **State Design Criteria** Wastewater systems must meet state design criteria. Most environmental regulations mandate meeting "performance" standards which allow the designer freedom to develop the best system for the conditions that will meet the preestablished performance standards. The design goal of any innovative wastewater system should be to meet all "performance" standards for discharge into ground water or receiving streams. Small wastewater systems, on the other hand, are based on state specified "design standards" or "minimum design" standards. Design standards are effective, easy to regulate and work effectively for commercially available components such as septic tanks or easily constructed items such as drain fields. With design standards, no attempt is made to measure or evaluate system performance. It is assumed, based on experience, that a system designed according to the standards will be effective. The disadvantage with design standards is that they allow the designer very little freedom, effectively eliminating innovative or unusual treatment processes. State approved design standards may not exist or may be inappropriate for an effective community cluster system.

2) **Sec 202 Eligibility** Many residences in the 202 area are ineligible for flood proofing or acquisition under the 202 program due to their location or constructed elevation. In addition, many eligible resident owners chose not to participate in the program. Yet these residences contribute to the community health problem along with the eligible buildings. Eliminating 10 "straight pipes" in a 50 home community discharging directly into a stream may do little or nothing for community health or environmental conditions. This raises several questions. If home owners are not eligible for flood proofing, would they be allowed to connec to the community system? Would they be required to connect to the system? Would they be required to pay to connect to the system?

3) **Existing Systems** Most home owners don't know if their septic system is performing adequately or not. When faced with a connection charge most owners will assume they have an effective working system. Generally when community systems are installed, home owners are required to connect to the new system regardless of the condition of their existing system, and are assessed for a share of the costs. In the 202 program septic systems are assumed adequate, unless a "straight pipe" is observed or the home owner complains or odors or other symptoms of a failed system. When designing community cluster systems what assumptions do we make about exiting systems?. Are all existing systems assumed to be ineffective? Should existing systems be tested? Should all owners be required to connect to the new system regardless of need?

4) **Communily Operations** Community systems must be properly operated and maintained. Maintenance includes pumping septic systems, monitoring performance, policing, and repair and rebuilding after flood events. What existing or new public organization will take over operation and maintenance of these systems? How will this activity be funded?

# Typical Cluster System

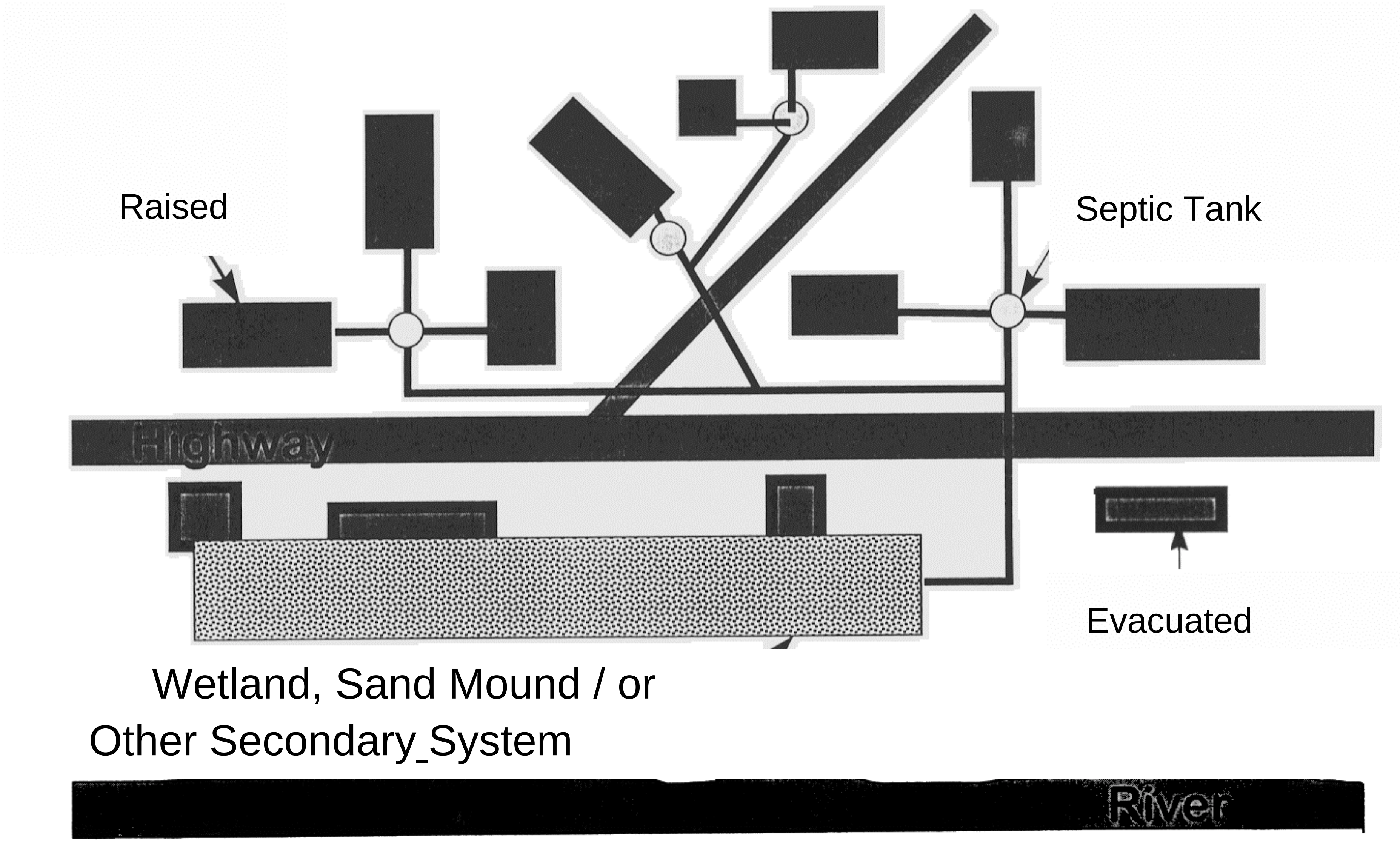
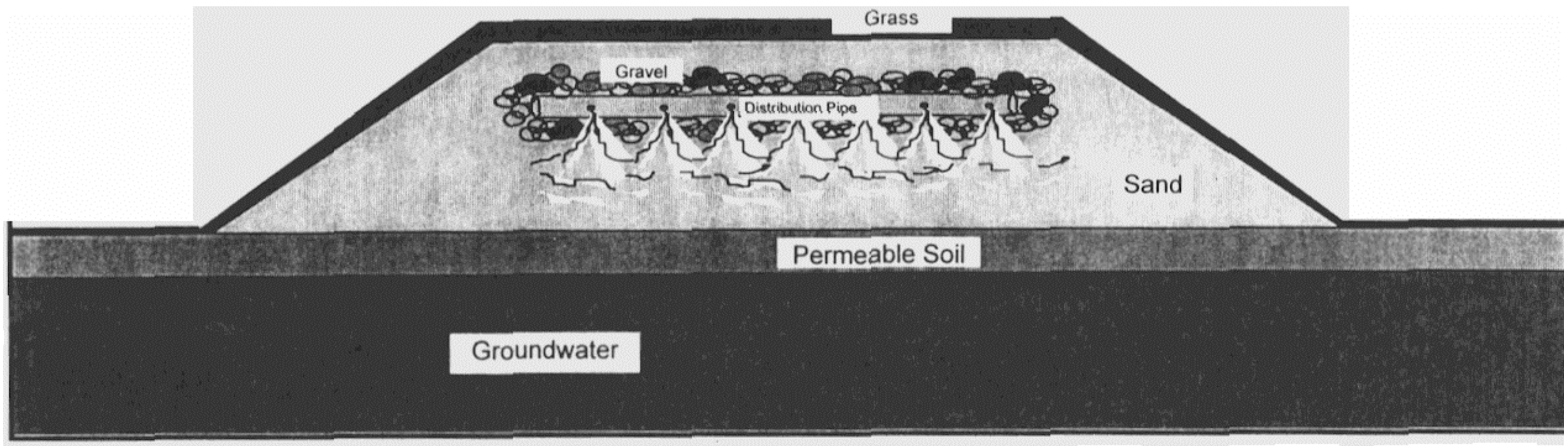
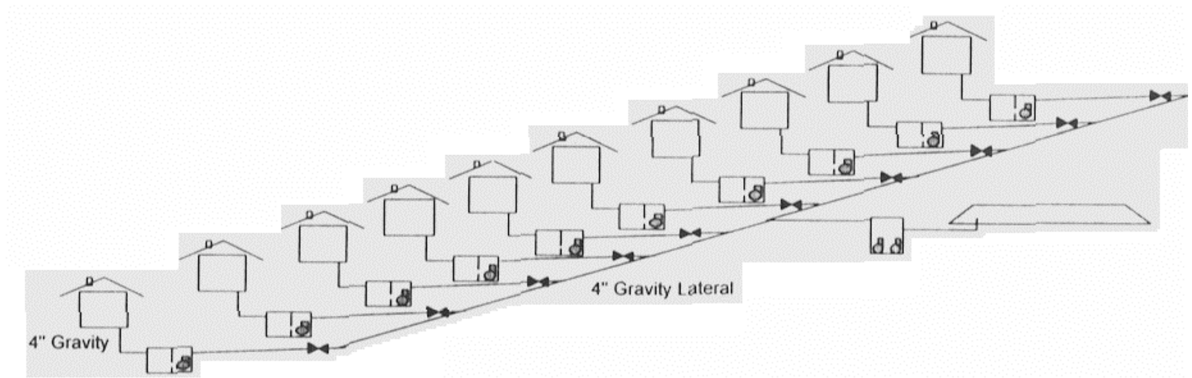


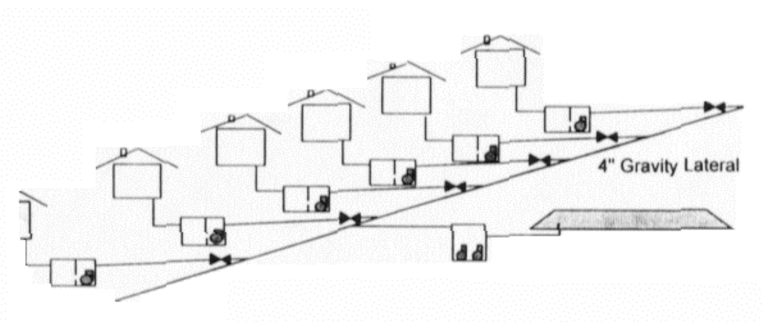

Figure #1

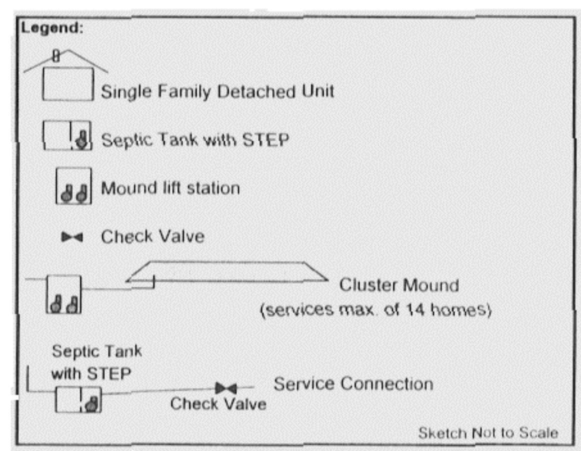
Cross-Section of Elevated Sand Mound System



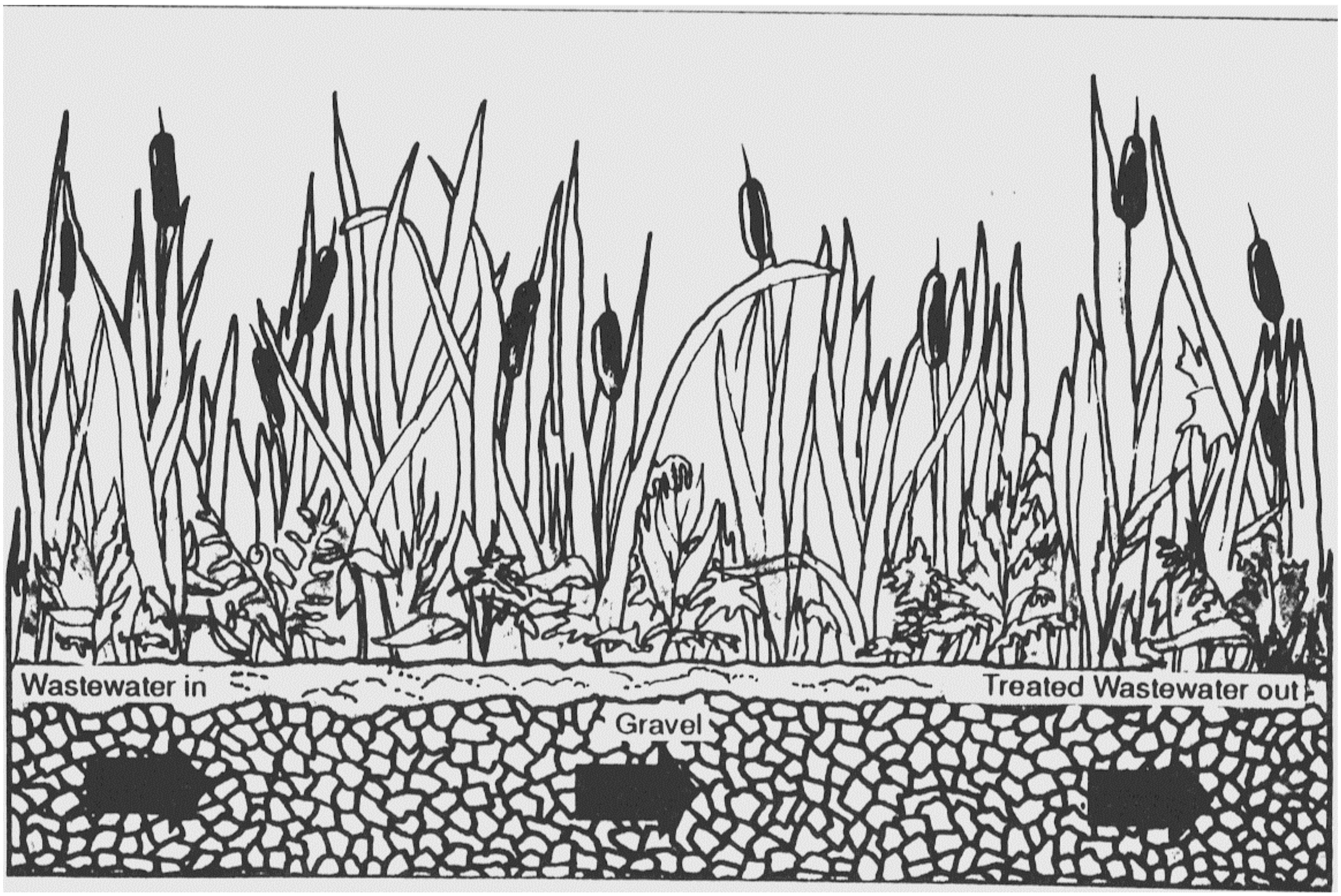
Sketch of Septic Tank Effluent Pumps (STEP) & Cluster Mound System

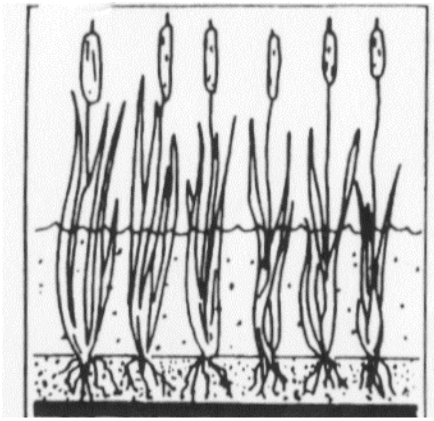


# Constructed Wetland



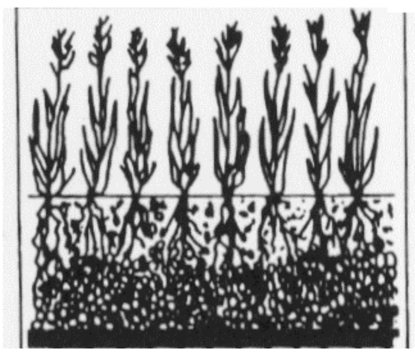


Water level is below ground; water flow is through a sand or gravel bed; roots penetrate to the bottom of the bed

WETLAND PLANTS AND WATER

SOIL
LINER
NATIVE SOIL

**SURFACE FLOW WETLAND**



Water level is above ground surface; vegetation is rooted and emerges above the water surface; water flow is primarily above ground

WETLAND PLANTS

SOIL, SAND, AND GRAVEL
LINER
NATIVE SOIL

**SUBSURFACE FLOW WETLAND**

Surface flow and subsurface flow constructed wetlands
(from Water Pollution Control Federation 1990)